

Appraisal of sorghum quality for making tô

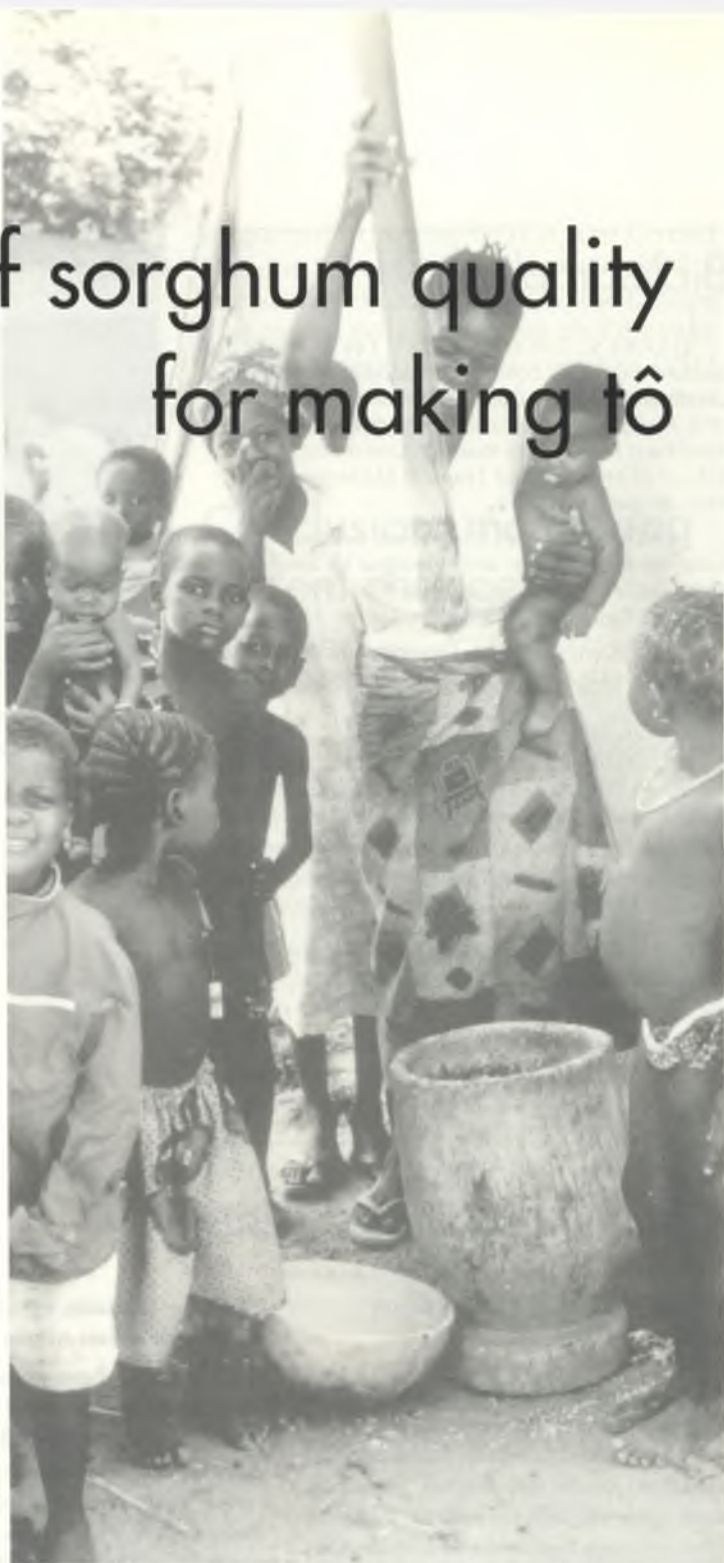
Tô is a traditional West African dish prepared from sorghum, millet or maize flour. Although improved sorghum varieties are agronomically productive, their technological and cooking qualities do not match those of local varieties.

A research study was conducted to assess these qualities and their determining factors. It is thus now possible to predict the technological potential of sorghum varieties during the breeding process.

Tô is a very thick cereal porridge usually eaten at the two main meals, garnished with a sauce, vegetables and sometimes meat. The leftover tô can be stored overnight and served the next morning, cold or warmed up, with milk or sauce.

The main quality criteria for a good tô in decreasing order of importance are its consistency (i.e. texture or firmness of the porridge), overnight keeping quality, colour and taste (not crucial, since it is dominated by the accompanying sauce). For African families, tô should be firm, unsticky, light coloured and keep its firmness overnight without any liquid exudation on the surface.

Only tô made with flour of local sorghum varieties can meet these criteria. Improved cultivars are more productive but often have poor technological and cooking



Pounding
sorghum grain.
Photo G. Fliedel

characteristics. Moreover, very few selected sorghum varieties proposed to farmers have been successfully cropped.

The Centre de coopération internationale en recherche agronomique pour le développement (CIRAD, France) has developed a laboratory test for tô preparation and evaluation of its quality; it should be a useful tool for breeders seeking to develop sorghum varieties with high technological and agronomic qualities. Some technological aspects of tô preparation procedure and some physico-chemical characteristics of the grain (variety-dependent) determine the ultimate consistency of the porridge.

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Traditional tô preparation

Tô is traditionally made from sorghum flour obtained after dehulling and grinding the grain with a mortar and pestle (Figure 1). This flour is always ground just prior to preparing the tô, as old flour cannot produce good tô¹. It is sifted to remove coarser particles and then a small amount is dispersed in cold water (two-thirds water, one-third flour) that has been acidified with lemon or tamarind juice, or alkalized with potassium (wood ash extract), depending on the culinary preferences of the consumers.

This "flour milk" is then poured into a pot of boiling water. A thin porridge is obtained after 5-8 min cooking; about one-third is set aside in a calabash. The rest of the flour is added by handfuls to the pot of porridge, while stirring vigorously with a flat wooden spoon. The porridge then thickens and becomes firm, smooth and uniform; some of the thin porridge that was set aside can be added if the mixture gets too thick. After 20 min cooking, the tô is ready to be eaten.

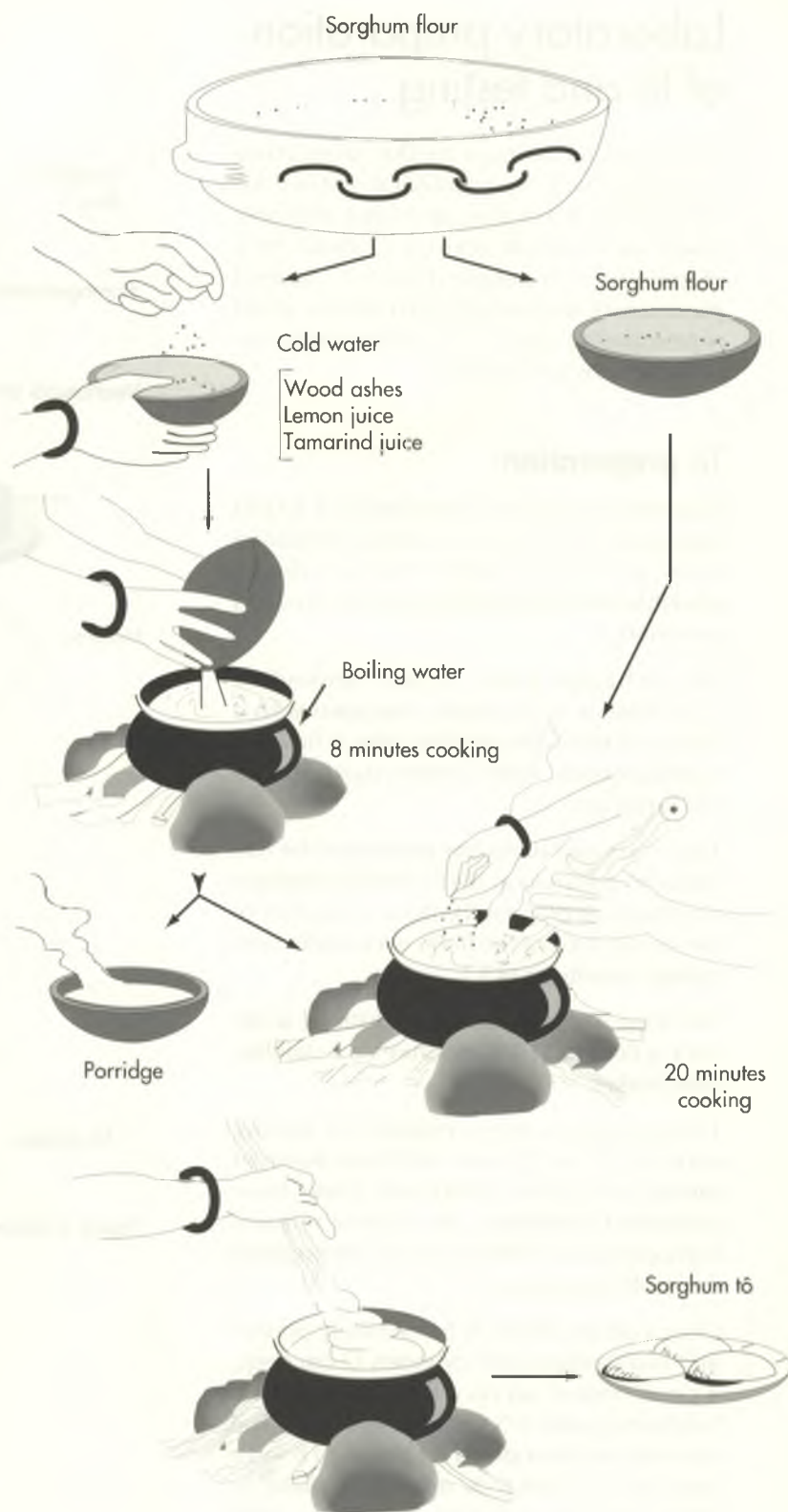


Figure 1. Traditional tô preparation procedure.



Tô prepared traditionally in Burkina Faso, final porridge obtained.

Photo P. Ollitrault

1. The fact that freshly ground, well-sifted flour has to be used considerably limits the manufacturing potential. Tô cooks do not like milled flours as they are considered to be too old and of poor quality (too high fat/bran contents).

Laboratory preparation of tô and testing

The main advantage of the laboratory technique over the traditional method for preparing tô is that it is carried out with only small quantities of grain, i.e. about 10 g of grain for a tô sample (Figure 2). Several parameters were studied to obtain good repeatability and better differentiation between sorghum varieties.

Tô preparation

Sorghum grain is first dehulled in a TADD laboratory dehuller at a constant dehulling yield² of about 75-80%, thus avoiding a possible dehulling effect on the final tô consistency.

The dehulled grain is then ground in a Cyclotec helical grinder equipped with a 500 µm screen. The resulting flour is fine and homogeneous, with a mean particle size of 75-100 µm.

These two operations are performed the day before tô preparation (24 h) since tô firmness was found to drop markedly as a function of the storage time of the flour, even under cold storage conditions (4°C).

The flour is slurried in 90 ml distilled water (16.6 g flour at 11.5% moisture) in a stainless steel beaker.

The porridge is then cooked in a boiling water-bath for 20 min with mechanical stirring (helix-stirrer at 400 rpm). Under these controlled conditions, the mixture remains homogeneous, without lumps, throughout the cooking process.

Once cooked, the tô is immediately poured into two stainless steel cylinders (2 cm deep, 4 cm diameter), set on a flat glass plate and heightened with 0.5 cm adhesive tape. The cylinders are then stored for about 20 h in an oven at 35°C and 85% relative humidity to limit surface-drying of the tô samples. After storage, the adhesive tape is removed and surplus tô is shaved off with nylon thread. Tô samples of constant size (3 cm diameter, 2 cm deep) are obtained with a hollow punch.

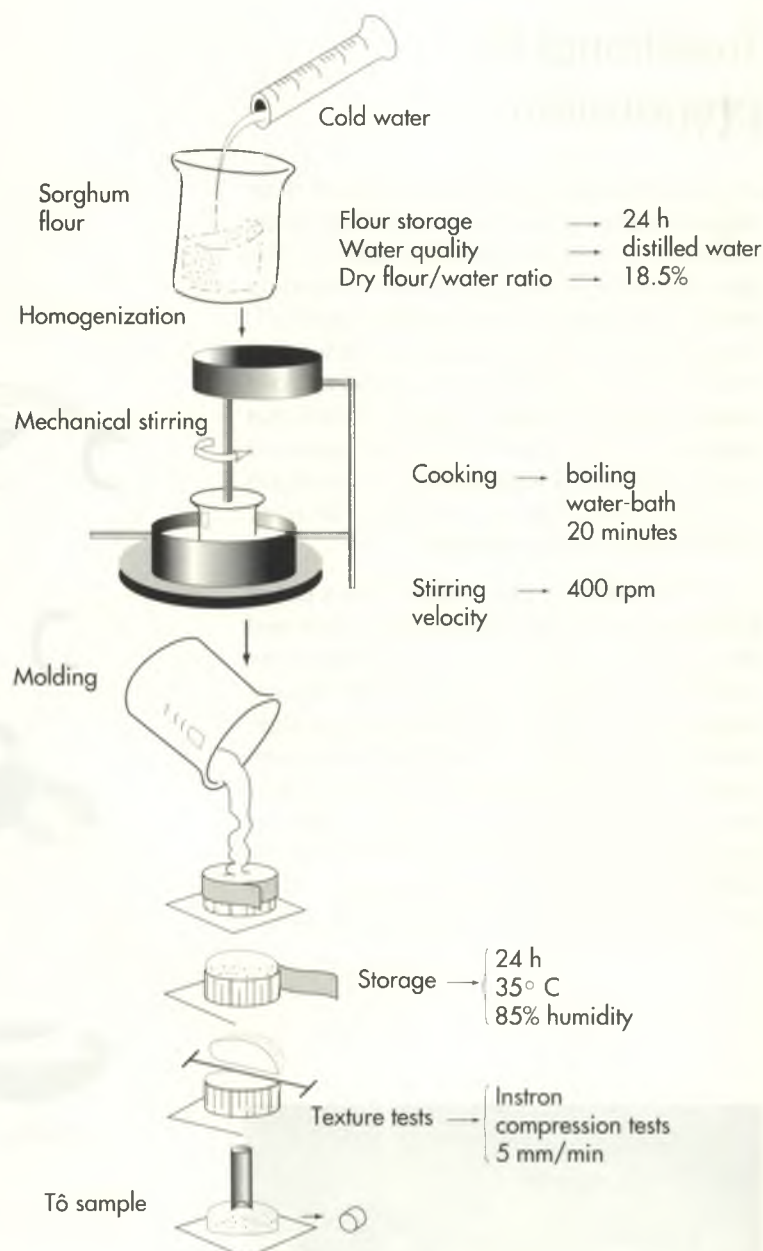


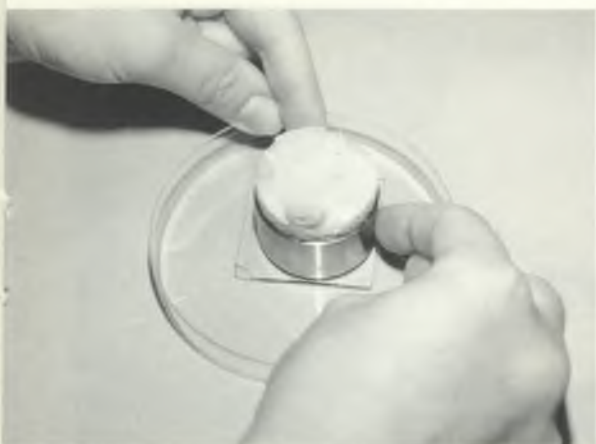
Figure 2. Laboratory preparation of tô.



Compression test of a tô sample with an Instron machine.

Photo T. Erwin

2. Dehulling yield is given as: dehulled grain weight/initial whole grain weight (%).



Preparation of a tô sample in the laboratory.

Photo G. Fliedel

Texture assessment

Tô sample texture is measured with an Instron universal food testing machine (model 4300). The samples are compressed between a metal plate and a piston lubricated with paraffin oil. Compressive strength (newtons [N]) is recorded as the piston compresses the sample (5 mm/min). The force required to break down a tô sample is monitored to measure tô texture because of better differentiation between varieties (Figure 3). Cooking tests are performed in duplicate for each sorghum variety, with two tô cylinders obtained after each cooking, so texture results are based on quadruplicate compression measurements. According to this method, tô samples differing in firmness by only 1 N are significantly different at $P = 0.05$.

This precise repeatable technique has been used to evaluate a great many cultivars during the breeding process, along with local varieties. A sorghum tô quality scale was thus established (Table 1).

Effect of technological characteristics

Tô consistency seems to be governed by the grain dehulling technique and flour particle size.

Grain dehulling

Two French varieties and 20 tropical varieties (local or improved) were analysed in terms of dehulling factors.

Marked dehulling effect

The two French varieties, available in large quantities and differing in terms of their hardness index (PSI: particle size index), were progressively dehulled for 19 min; flours obtained from the dehulled grain were used to make tô.

Tô consistency was found to be substantially affected by dehulling (Figure 4). The firmness of the porridge increased as grain abrasion increased, reaching a plateau at 11 min dehulling time (corresponding to a dehulling yield of about 70%). The results were significant ($P < 0.05$) at five different dehulling times: 0, 1, 3, 5 and 15 min.

A highly significant correlation between dehulling yield and tô firmness (correlation coefficient $r = -0.74^{**}$) was obtained when all 20 varieties were processed for the five significant dehulling times (Figure 5). Nevertheless, there was marked variability between varieties. For instance, flour ground from whole grain (undehulled) produced tô with a texture range of about 5-14 N. Note that, regardless of the variety, tô quality was never poor (breaking force higher than 12 N) at dehulling yields of less than 75%.

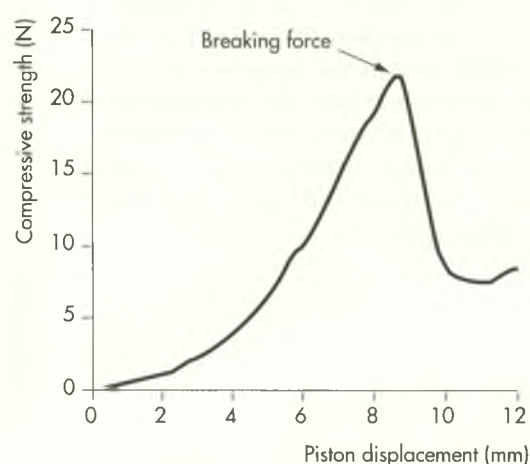


Figure 3. Graph of compression test results (Instron machine) for a tô sample compressed between a metal plate and a piston (compression rate: 5 mm/min).

Table 1. Sorghum tô quality scale.

Breaking force (newtons)	Tô texture	Tô quality
< 10	very soft	very poor
10-12	soft	poor
12-15	acceptable	acceptable
15-18	firm	good
> 18	very firm	excellent

How grain composition is modified

During the abrasion process, the outer grain layers are chafed away, thus changing the dehulled grain composition. The tô firmness results indicated a negative correlation with the flour mineral content ($r = -0.80^{**}$), fat content ($r = -0.64^{**}$), fibre content ($r = -0.74^{**}$) and even the protein content ($r = -0.60^{**}$). Conversely, there was a positive correlation with starch content ($r = +0.74^{**}$). In our conditions, the protein content varied according to the extent of grain dehulling, i.e. the longer the dehulling time – the lower the protein content, whereas the starch content increased on the basis of dry matter.

When dehulling was sufficient, i.e. when removal of the outer layers and germ was suitable, the resulting tô was never of poor quality. Indeed, regardless of the sorghum variety, a breaking force higher than 12 N was obtained with a flour mineral content of less than 1% (Figure 6), and a fat content of less than 2% (Figure 7).

Flour particle size

Several sorghum varieties were dehulled to the same yield (about 75-80%) and then ground in nine different types of mills to produce flours of different particle sizes, but with the same biochemical composition. Depending on the mill used, the mean particle size ranged from less than 75 μm (Cyclotec or Alpine mill) to more than 900 μm (KT30 mill).

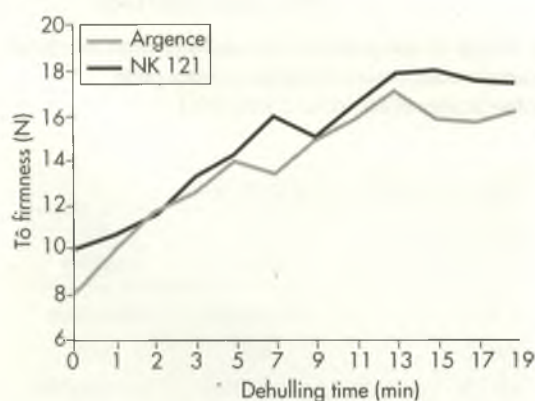


Figure 4. Effect of dehulling time on tô firmness for two French sorghum varieties.



Tô preparation:
adding dry flour
to the thin porridge.
Photo G. Fliedel

Good tô with fine flours

With the same sorghum variety, tô quality ranged from very good to very bad depending on the flour particle size. Very fine flours (mean particle size less than 150 μm) produced acceptable or good tô (breaking force above 12 N), contrary to coarse flours.

Starch effect

Starch occurs in granular form in the grain endosperm. These granules can be broken (damaged) during milling, especially with fine milling (e.g. tightly adjusted millstones).

Damaged starch levels were evaluated in the finest milling products (mills: Cyclotec 0.5 mm, Cyclotec 1 mm, Alpine, Miag,

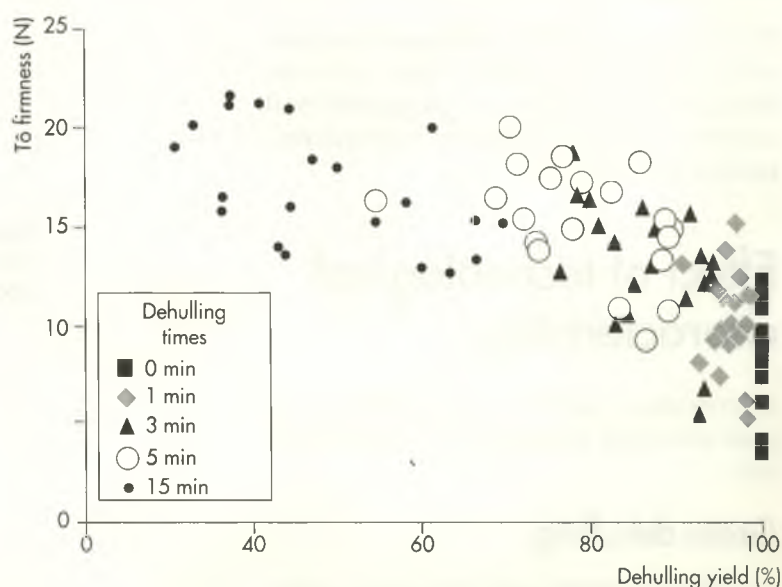


Figure 5. Relation between tô firmness and dehulling yields for 20 tropical sorghum cultivars, and five different dehulling times.

Samap). It was significantly and negatively correlated with the particle size of these flours ($r = -0.69^{**}$): very fine flours had much higher damaged starch levels than coarse flours.

Tô quality was positively correlated with damaged starch levels of the flours ($r = +0.49^{**}$). Hence, flours with high damaged starch levels generally produced firmer tô than those containing coarse particles and with low damaged starch levels.

This physical effect seemed to be more important for flours from sorghum varieties that naturally produced good tô (Figure 8). For instance, the regression coefficient between tô firmness and the percentage of damaged starch was sixfold higher for variety IS 15255 (of the good quality variety group) as compared to IS 24761 (of the poor quality variety group).

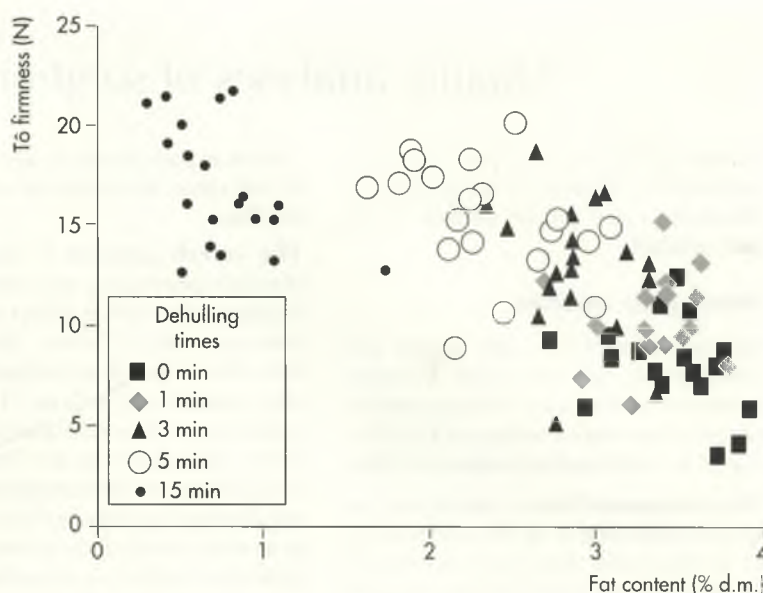


Figure 7. Relation between tô firmness and the flour fat content for 20 tropical sorghum cultivars and five different dehulling times.

Effect of physico-chemical grain characteristics

18 sorghum cultivars from Mali and Burkina Faso were analysed. Their tô firmness results ranged from 9.5 to 22.4 N (mean 14.2 N), which generally corresponded to a good quality tô.

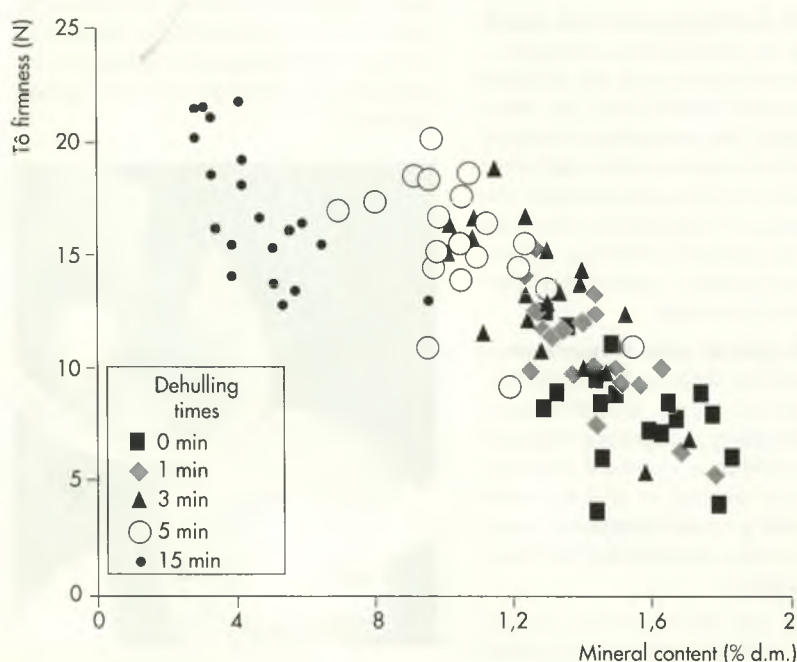


Figure 6. Relation between tô firmness and the flour mineral content for 20 tropical sorghum cultivars and five different dehulling times.

Vitreousness, hardness and protein content have no impact

Despite wide variability in the vitreousness and hardness (PSI) indexes, which ranged from 1.7 (vitreous grain) to 4.9 (floury grain) and 12.1 (hard grain) to 28.4 (soft grain), respectively, there were no significant correlation between these physical grain characteristics and tô texture. Moreover, vitreous grains were generally hard and floury grains generally soft.

Similarly, total proteins and protein fractions in the flour were not significantly correlated with tô consistency, again despite a wide range of results for each of these chemical components. In this case, the grain dehulling yields were constant and thus the protein content was that of the endosperm; but these proteins did not have as important an effect on tô quality as starch.

Effects of starch

In contrast, starch characteristics were found to be highly and significantly correlated with tô texture, particularly in terms of the starch amylose content ($r = +0.81^{**}$) and starch solubility at 85°C, the temperature at which tô is cooked ($r = +0.86^{**}$). Therefore, the tô becomes firmer as the amylose content increases and starch macromolecules solubilize better at 85°C (Table 2).

Quality analyses of sorghum used to make tô

These laboratory analyses are only performed on whole grains or flours. However, some can be used to assess both products.

Whole grain analyses

Before all analyses, the grains are cleaned (to eliminate dust, glumes, broken kernels) and conditioned to obtain a moisture content of 11-12%, a level at which hardness varies very little.

The vitreousness index is determined by visual assessment of the proportion of vitreous and floury endosperm on 20 longitudinal half kernels cut with a razor blade. Each grain is graded on a 1-5 scale (± 0.25 points); a score of 1 corresponds to a totally vitreous endosperm, and 5 to a totally floury endosperm.

The hardness index (PSI: particle size index) is determined after milling 20 g of grain in a Falling Number KT 30 type mill (coarse burr, setting 4) and 1 min sifting of milled material through a 250 μm sieve (Alpine type 200 LS air jet sifter). PSI represents the percentage of milled material passing through the sieve. The lower the PSI, the harder the grain.

The dehulling yield is obtained after 5 min grain dehulling in a Tangential Abrasive Dehulling Device (TADD). This laboratory dehuller is equipped with a carborundum abrasive disk that turns horizontally under a steel plate with eight sample cups. Each cup is filled with 30 g of grain, and eight different varieties can be processed at once. The dehulling yield is the percentage dehulled grain weight/initial whole grain weight (30 g).

Flour analyses

Flours are prepared by grinding the dehulled grain (constant dehulling yield of 75-80%) in a Cyclotec helical mill.

The mean particle size is determined by successive sievings, from a 75 μm mesh sieve to a 2 000 μm sieve, depending on the flour; there is a total of 16 sieves (75, 100, 125, 150, 180, 200, 250, 315, 400, 450, 710, 800, 900, 1000, 1400 and 2000 μm). These sifting tests are performed with 50 g samples of flour at constant low humidity (about 10-11%) through an Alpine air-jet sifter for 5 min. The percentage of flour that does not pass through each sieve is measured.

The mean particle size G 50 corresponds to the sieve mesh that retains 50% of the flour.

The starch content is determined through enzymatic and colorimetric analyses. The starch is first gelatinized between 80°C and 90°C, and then dextrinized with thermamyl, a thermostable amylase. Through a reaction with amylo-glucosidase at 55°C, the dextrans are hydrolysed into glucose, which is measured by spectrophotometry after reaction with an enzymatic oxydo-reducer enzyme-stain (glucose-oxydase, peroxydase, ABTS) system. Using a standard scale, the glucose concentration of the sample is determined, along with its starch content, by multiplying by the conversion factor (0.9).

The amylose content is evaluated by the ISO 6647 standard colorimetric technique. The flour is first defatted with 85% methanol, remilled and solubilized in a mixture of 95% ethanol and normal soda. Amylose staining is done in the presence of a solution of molecular iodine and iodide ions (potassium iodide). The optical density of each sample is measured with a spectrophotometer at 620 nm and compared to that of a standard scale prepared from different mixtures of control amylose and amylopectin.

The starch swelling power and starch solubility are measured as follows: a flour-water mixture (1 g/25 ml) is stirred in a water-bath at 85°C for 1 h. After centrifugation, the percentage of soluble starch in the water is obtained after desiccation of the supernatant; the quantity of water absorbed by the flour starch; i.e. starch swelling power (g water/100 g d.m.) is determined after desiccation of the pellet.

The starch gelatinization temperature is determined by differential scanning calorimetry analysis, which is used to measure energy variations required to heat a sample at constant velocity. The flour is placed in a watertight capsule with a certain amount of water and the mixture is subjected to linear heating kinetics.

Extraction and measurement of four protein fractions were performed sequentially with different solvents:

- albumins and globulins with a saline solution (0.5 M NaCl);

- prolamins or kafirins with a 60% ter-butanol solution;
- reduced prolamins (or reduced kafirins) with a 60% ter-butanol solution containing 0.1 M 2-mercaptoethanol;
- glutelins with a borate buffer solution (pH 10) containing 0.6% 2-mercaptoethanol and 0.5% sodium dodecylsulfate.

Proteins were measured in the supernatants by the method used for total proteins (described below).

Chemical analyses of whole grain and flour

The water content (moisture) is determined according to the NF V03.707 standard, from 5 g samples, by differential weighing after 2 h oven-drying at 130°C.

The mineral content is determined according to the NF V03.702 standard, from 5 g samples, by differential weighing after 3 h calcination at 900°C.

For fat content, the Soxhlet extraction technique is used with a Tecator Soxtec HT distiller. Fats are extracted at 100°C by soaking and rinsing the sample in diethyl ether. Ether-soluble fat contents (or free fats) are determined by weighing the extracted fats after desiccation.

Total protein content (% N x 6.25) is measured after the sample is mineralized with concentrated sulfuric acid in the presence of a catalyst (99.5% potassium sulfate + 0.5% selenium), by the Kjeldahl method with a Tecator automatic Kjeltac apparatus.



Tô preparation: washed sorghum being poured into a mortar.

Photo G. Fliedel

Progressive multiple linear regressions highlighted that 79% of the tô firmness could be positively explained by the starch macromolecule solubility in water at 85°C and negatively by the starch granule swelling power. When solubility and swellingness factors were not taken into consideration, 65% of tô firmness could be explained by starch amylose content.

Tô texture, like the consistency of a mixed starch gel, depends on the viscosity of the liquid phase — which increases with the quantity of solubilized macromolecules, especially amylose — and also on the firmness of the solid phase — which increases when the starch granules are not very swelled.

Flours from varieties with high amylose content (more than 25% starch) generally produce good tô. They are often vitreous or have a vitreous tendency. Moreover, varieties containing high water soluble starch (above 18% d.m. at 85°C), also produce good tô.

Starch solubility increased with the percentage of damaged starch, e.g. during fine milling, but this also depended on the variety. There was a positive correlation between the amylose content and the starch solubility at 85°C ($r = +0.84^{**}$). In fact, starches from high amylose sorghum varieties are highly soluble during the tô cooking process.

Conclusion

The laboratory test described here for tô preparation and textural assessment is precise and repeatable. In addition, it has the advantage of only requiring small grain quantities. Breeders could use this test to evaluate the quality of cultivars during the breeding process. The results clearly demonstrate that tô quality is dependent on the technology used in its preparation and on the sorghum variety.

Grain dehulling is also a very critical operation. All of the outer grain layers have to be chafed off in order to produce tô of suitable quality. Hence, it is essential to select sorghum varieties with good dehulling properties — with grains that are not too soft, not too floury and that will not break during manual or mechanical dehulling.

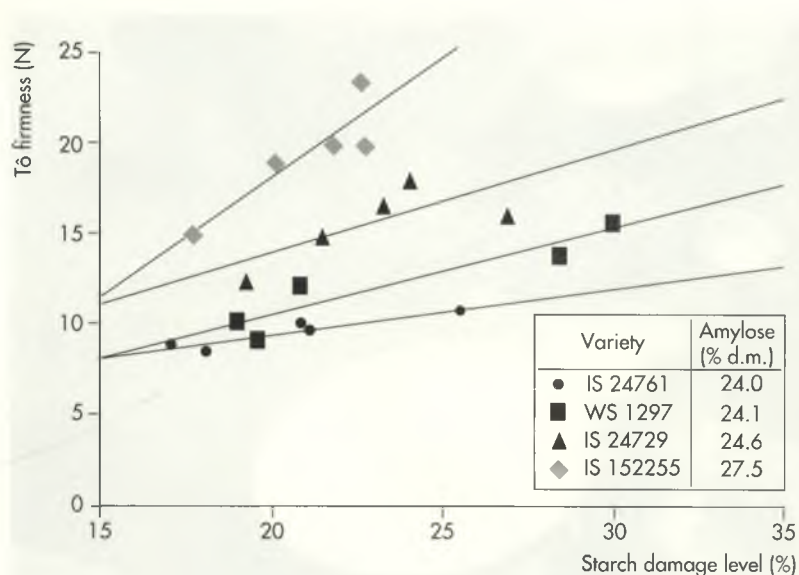


Figure 8. Effect of the starch damage level in flours from four sorghum cultivars on tô firmness.

Grinding of dehulled grain is also a quality factor. Tô firmness is linked with the flour damaged starch content (higher in fine than in coarse flours), which promotes starch macromolecule solubility during cooking. High amylose varieties (25% higher on a starch basis) with high starch solubility at 85°C, produce high quality tô. However, with the same starch solubility, tô firmness depends on the extent of starch granule swelling power, i.e. the lower the water uptake, the firmer the tô.

Table 2. Relationships between the flour starch characteristics of 18 West African sorghum varieties and tô texture.

Characteristics	Minimum	Maximum	Mean	Correlation coefficient
Starch (% d.m.)	68.5	79.7	76.6	0.27
Amylose (% starch)	19.6	29.3	24.7	0.81**
Gelatinisation temperature (°C)	72.3	74.5	73.3	- 0.23
Starch solubility (% d.m.)	12.2	23.9	16.2	0.86**
Starch swelling power (grams water % d.m.)	8.8	11.8	9.7	0.23
Tô firmness (N)	9.5	22.4	14.2	1

** : highly significant at $P = 0.10$.



Tô preparation: before serving, some of the porridge is poured into a small calabash.

Photo G. Fliebel

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Abstract... Resumen... Résumé

G. FLIEDEL — Appraisal of sorghum quality for making tô.

Tô is a traditional porridge prepared daily in West Africa from sorghum, millet or maize flour. The porridge must be firm to be appreciated. Good quality tô depends on the technology used in flour preparation (dehulling and milling) and the physico-chemical characteristics of the grain. A laboratory method for the preparation of sorghum porridge and appraisal of its firmness is available for breeders for the prediction of the technological and cooking quality of the varieties being bred. Dehulling plays an important role because much of the outer layers of the grains as possible should be removed. Likewise, the dehulled grain should be milled to fine flour for making firm tô. A strong positive correlation was found between firmness and the amylose content of flours and starch solubility at 85°C. The amylose content varies according to the sorghum variety. It would seem opportune in varietal improvement of sorghum to determine dehulling suitability of the grain on the one hand and its amylose-starch content on the other to assess suitability for making firm tô. In contrast, characteristics such as grain vitreousness and hardness are not determinant.

Keywords: sorghum, flour, porridge, technology, cooking quality, variety, starch, laboratory analysis, West Africa.

G. FLIEDEL — Evaluación de la calidad del sorgo para la fabricación del tô.

El tô es una papilla tradicional preparada a diario en África occidental a partir de una harina de sorgo, mijo o maíz. Para ser apreciada, esta papilla debe ser firme. La obtención de un tô de buena calidad depende de la tecnología empleada para su preparación (descascarillado y molienda de los granos) y de las características físico-químicas de los granos. Un método de laboratorio de preparación del tô de sorgo y de evaluación de su firmeza se encuentra disponible para los seleccionadores con el fin de prever la calidad tecnológica y culinaria de las variedades que se estén seleccionando. El descascarillado de los granos desempeña un papel importante y requiere eliminar al máximo las capas periféricas del grano. Asimismo, la molienda de los granos descascarillados debe dar harinas finas para obtener un tô de firmeza correcta. Se ha puesto de relieve una fuerte correlación entre la firmeza del tô y el contenido de amilosa de las harinas, así como la solubilidad del almidón a 85°C. El contenido de amilosa varía en función de las variedades de sorgo. Para la mejora varietal del sorgo, parece indicada determinar la aptitud al descascarillado de los granos y, por otro lado, su contenido de amilosa-almidón con objeto de evaluar la capacidad de fabricación de un tô de buena firmeza. En cambio, las características como la vidriosidad y la dureza del grano no son determinantes.

Palabras clave: sorgo, harina, papilla, tecnología, calidad culinaria, variedad, almidón, análisis de laboratorio, África occidental.

G. FLIEDEL — Evaluation de la qualité du sorgho pour la fabrication du tô.

Le tô est une bouillie traditionnelle préparée quotidiennement en Afrique de l'Ouest à partir d'une farine de sorgho, de mil ou de maïs. Cette bouillie doit être ferme pour être appréciée. L'obtention d'un tô de bonne qualité dépend de la technologie employée pour sa préparation (décortiquage et broyage des grains) et des caractéristiques physico-chimiques des grains. Une méthode de laboratoire de préparation du tô de sorgho et d'évaluation de sa fermeté est disponible pour les sélectionneurs afin de prédire la qualité technologique et culinaire des variétés en cours de sélection. Le décortiquage des grains joue un rôle important et nécessite d'éliminer au maximum les couches périphériques du grain. De même, le broyage des grains décortiqués doit donner des farines fines pour obtenir un tô de bonne fermeté. Une forte corrélation positive a été mise en évidence entre la fermeté du tô et la teneur en amylose des farines, ainsi que la solubilité de l'amidon à 85 °C. La teneur en amylose varie en fonction des variétés de sorgho. Pour l'amélioration variétale du sorgho, il apparaît opportun de déterminer l'aptitude au décortiquage des grains d'une part, puis leur teneur en amylose-amidon d'autre part, afin d'évaluer la capacité à la fabrication d'un tô de bonne fermeté. En revanche, les caractéristiques telles que la vitrosité et la dureté du grain ne sont pas déterminantes.

Mots-clés : sorgho, farine, bouillie, technologie, qualité culinaire, variété, amidon, analyse de laboratoire, Afrique de l'Ouest.